IBM Technical Papers Published Recently in Other Journals

Absorption Data of Laser-Type GaAs at 300° and 77°K, W. J. Turner and W. E. Reese, *Journal of Applied Physics* **35,** No. 2, 350-352 (February, 1964).

Optical absorption coefficients have been determined at 300 and 77°K for samples of GaAs which were doped to concentrations comparable to those present in the *n, p,* and *p+* regions of the GaAs injection laser. *n*-type GaAs doped with Te to 3×10^{17} cm^{-3} and 9.6×10^{17} cm^{-3} have absorption coefficients of 20 cm^{-1} and 10 cm^{-1}, respectively, at 1.475 eV and 77°K. Free carrier and deep-level absorptions contribute approximately 5 cm^{-1} to these values. At 77°K, *p*-type Zn-doped samples with $N_A - N_D$ equal to 1.6×10^{18} cm^{-3} exhibit in the spectral region of laser emission an absorption that increases exponentially with photon energy and probably results from transitions of electrons in acceptor states to levels in the conduction band or conduction band tail. At 1.475 eV and 77°K, the absorption coefficient of this *p*-type material is 225 cm^{-1} to which free carrier absorption contributes only 3 cm^{-1}. For heavier Zn-doped *p+* material, e.g., 7×10^{19} cm^{-3}, the value of K at 77°K and 1.475 eV is 250 cm^{-1} and is entirely due to free carrier absorption. For both *n* and *p* materials, a Burstein shift of the edge to higher energies is observed for the heavily doped materials in agreement with the observations of others.

Accuracy of Computed Spectroscopic Constants from Hartree-Fock Wavefunctions for Diatomic Molecules, A. D. McLean, *The Journal of Chemical Physics* **40,** 243-244 (January, 1964).

Spectroscopic constants for the H_2 and LiF are computed from the ground state Hartree-Fock potential curves, and compared with the experimentally observed quantities. Discrepancies are related back to functional inadequacy in the Hartree-Fock solutions over and above the neglect of electron correlation.

An Algorithm For The Traveling Salesman Problem,† John D. C. Little,* Katta G. Murty,** Dura W. Sweeney and Caroline Karel,*** *Operations Research* **11,** No. 6, 972-989 (November-December, 1963).

A "branch and bound" algorithm is presented for solving the traveling salesman problem. The set of all tours (feasible solutions) is broken up into increasingly small subsets by a procedure called *branching*. For each subset a lower bound on the length of the tours therein is calculated. Eventually, a subset is found that contains a single tour whose length is less than or equal to some lower bound for every tour. The motivation of the branching and the calculation of the lower bounds are based on ideas frequently used in solving assignment problems. Computationally, the algorithm extends the size of problem that can reasonably be solved without using methods special to the particular problem.

† Work performed while K.G.M. was on study assignment at Case Institute of Technology, Cleveland, Ohio, and while D.W.S. was Sloan Fellow at Massachusetts Institute of Technology, Cambridge, Mass.
*•Massachusetts Institute of Technology.
** Indian Statistical Institute.
*** Case Institute of Technology.

Analytical Methods in Transportation: Mathematical Car-Following Theory of Traffic Flow, Denos C. Gazis, Robert Herman* and Richard W. Rothery,** *Journal of the Engineering Mechanics Division, Proceedings of the American Society of Civil Engineers,* **89,** EM 6, 29-46 (December, 1963).

A mathematical theory that attempts to describe the detailed manner in which one vehicle follows another in a single lane is reviewed. According to this theory, the motion of a line of cars is described by a system of differential difference equations. The parameters entering these equations have been obtained by a series of car-following experiments.

Stability criteria, as well as steady-state flow relationships between density, speed, and volume of traffic, are presented. In order to test the validity of this car-following model for single lane traffic flow, comparisons are made with a number of experiments and observations.

* Head, Dept. of Theoretical Physics, General Motors Research Laboratories, Warren, Mich.
** Dept. of Theoretical Physics, General Motors Research Laboratories.

Anelastic Piezoresistance Effect in Alloys, B. S. Berry and J. L. Orehotsky, *Philosophical Magazine* **9,** 467-484 (March, 1964).

Experiments are described which established the existence of a new "anelastic piezoresistance" effect. The effect consists of a change in the electrical resistivity of a sample as a result of stress-induced directional ordering. This change has been detected in polycrystalline Ta-O, Ag-Zn, Ag-In, Cu-Zn and Cu-Mn alloys, which undergo stress-induced ordering by either the Snoek or Zener mechanism. Values obtained for the anelastic strain coefficient of resistivity were, with the exception of the Ag-Zn alloys, much larger than the corresponding elastic strain coefficient. This result suggests that in general the long-range strain sur-

rounding a relaxation center is not an important factor in determining the resistivity contributed by the center. It is shown from formal considerations that, for the case of the Snoek relaxation, the anelastic strain coefficient of resistivity is an isotropic crystal property. With this result, data obtained on Ta-O have been analyzed to yield the two resistivity parameters which define the anisotropy of the scattering cross section of the interstitial oxygen atoms. For current flow parallel and perpendicular to the tetragonal axis associated with the interstitial oxygen atoms, it is deduced that the resistivity is, respectively, 5.7 and 4.8 μ-ohm cm/at. % oxygen. Results for the substitutional alloys are discussed qualitatively in terms of current knowledge of the mechanism of the Zener relaxation.

Angular Displacement of Visual Feedback in Motion and Learning,† John D. Gould and Karl U. Smith,* *Perceptual and Motor Skills* **17,** 699-710 (1963).

Closed-circuit television techniques were used to displace the line of sight of human operators and evaluate the hypothesis that such displacement produces no disturbance of behavior within a limited "normal" range, but that a breakdown angle can be found beyond this range which will produce disturbance in human motor performance in proportion to the magnitude of feedback displacement. Results with two different motor tasks demonstrate the validity of this hypothesis and indicate that the effects of angular visual displacement depend upon the motion pattern involved.

† Work performed at the University of Wisconsin, Madison, Wisconsin.
* University of Wisconsin.

The Applicability of AISI C-1213 Free-Machining Steel to Complex Fatigue-Shock-Wear Load, G. Koves, *Transactions of the Metallurgical Society of AIME* **230,** 58-66 (February, 1964).

The behavior of case-hardened AISI C-1213 free-machining steel under complex impact-fatigue-wear load conditions was investigated. The inherently poor dynamic properties of the steel are mainly affected by the stress distribution in the case, component shape, and tempering. Cold-riveted components showed unexpectedly high dynamic strength compared to basic parts. A compromise treatment—which provides good dynamic properties, reasonable wear resistance, and fair riveting characteristics—was developed.

The Application of Linear Programming Techniques in Process Control, D. R. Kuehn and J. Porter, *IEEE Transactions on Industrial Electronics and Control Instrumentation* **IECI-11,** No. 1, 64-70 (February, 1964).

Many process control applications require a determination of optimum process position, subject to input (manipulated) variable bounds and to output (controlled) variable constraints. While the general idea of using linear programming (LP) to perform this determination is not new, this paper stresses how LP can be effectively used on a control computer. Development of three useful concepts is described, followed by a description of a modified simplex algorithm which incorporates these concepts. The three concepts are, (1) move penalties, (2) target constraints, and (3) temporary constraint violations.

The algorithm, based on the modified simplex procedure has been successfully applied to three operating IBM computer-controlled processes: catalytic cracking, crude distillation, and refining. Operating experience in application of the LP techniques to these processes is discussed.

Based on this experience, it is anticipated that an IBM 1710 Control Computer System with a 20,000-character storage, working in floating point with a 6-digit mantissa, could accommodate a problem with as many as 20 inputs and 80 outputs. By reducing storage requirements and running time to a minimum and by incorporating such features as move penalties, target constraints, and dead zones, the LP approach can be a powerful and effective optimization method for many process control problems.

Application of Pushdown-Store Machines, R. James Evey, *AFIPS Conference Proceedings* **24,** Fall Joint Computer Conference, 215-227 (1963).

A hierarchy of six sets of machines, bounded at the top by Turing machines, is defined by adding counters and pushdown stores to finite-state machines. Each set of machines is then partitioned in two ways: (a) Into accepters (machines with only inputs) and transducers (machines with both inputs and outputs), and (b) Into deterministic and nondeterministic machines (following Rabin and Scott). The set of all inputs to a machine is called its domain and the set of all outputs of a transducer is called its range.

It is proved that: (a) A set of sequences L is the domain of a nondeterministic accepter of a given type if, and only if, L is the range of a deterministic transducer of the same type; and (b) A set of sequences L is a context-free phrase-structure language if, and only if, it is the range of a deterministic pushdown-store transducer.

These facts are then related to theorems proved by Chomsky, Ginsburg, and Bar-Hillel, and to results produced in the field of language translation (both artificial and natural languages) by Samelson and Bauer, Oettinger, and Yngve.

Application of Spin Wave Theory to EuS,† S. H. Charap and E. L. Boyd, *The Physical Review* **133,** A811-A-818 (February 3, 1964).

Magnetization data for EuS powder in zero field and at liquid-helium temperatures has been obtained by nuclear magnetic resonance of both the Eu^{151} and Eu^{153} nuclei. These data are considered simultaneously with those for the specific heat of EuS powder obtained by McCollum and Callaway in order to provide a more definitive application of the spin-wave theory to this material. The theory is that given by Holstein and Primakoff and special attention is given to the effects of magnetic dipolar coupling on the spin-wave energy and moment. The calculation was carried out by summation over the exact Brillouin zone. Values of the nearest-neighbor exchange interaction J_1 and second-neighbor exchange J_2, as well as an effective field H which simultaneously produced resonable agreement between calculation and experiment are $J_1 = 0.20 \pm 0.01$°K, $J_2 = -0.08 \pm 0.02$°K and $H = 4.0 \pm 0.2$ kOe. These values are fairly consistent with other parameters known for EuS.

† This work supported in part by the U. S. Air Force Office of Scientific Research of the Office of Aerospace Research, under contract AF 49(638)-1230.

Application of the Uncertainty Principle to Electron Scattering by Phonons in Solids, T. N. Morgan, *The Journal of Physics and Chemistry of Solids* **24,** 1657-1661 (December, 1963).

The contribution of the uncertainty principle to the scattering rates of electrons by phonons in non-polar semiconductors is derived and applied to the hot electron problem. It is shown to modify all the transport integrals to a certain extent and to remove a singularity appearing in the expression for the mobility when expanded in powers of the electric field. This singularity results from the occurrence of an abrupt threshold for the emission by an electron of an optical phonon. The contribution to the mobility of the term in question and its dependence on the energy uncertainty are calculated for conduction in *n*-type germanium.

Approximate Relativistic Correction for 10-18 Electrons in Atoms, Enrico Clementi, *Journal of Molecular Spectroscopy* **12,** 18-22 (January, 1964).

The eigenvalues for the relativistic Hamiltonians for the isoelectronic series with 10 to 18 electrons and with atomic number Z from 10 to 36 were obtained by perturbation theory from the computed Hartree-Fock functions. To the computed relativistic energies I have added an empirical estimate of the spin-orbit energy, making use of the experimental spin-orbit splitting in the atomic spectra. The data we have obtained shows that the contribution of the relativistic energy to the total energy is very important even for atomic systems which are well described in the *L-S* coupling scheme.

Associative Logic for Highly Parallel Systems, R. R. Seeber and A. B. Lindquist, *AFIPS Conference Proceedings* **24,** Fall Joint Computer Conference, 489-494 (1963).

Some of the advantages of a highly parallel system include: high-order redundancy for high reliability; graceful deterioration; and modular enhancement. Complex real-time problems of supreme urgency will require a high degree of parallelism if they are to be solved. All of these points assume an exceedingly flexible means of programming and control for the system. Further, a high degree of parallelism with modules of low complexity may be the key to the economic mass fabrication of logic units in a technology such as cryogenics.

Other proposals have been typified by central "global" control with stringent problem symmetry requirements or by distributed "local" control with difficult programming. Our control might be called "autonomous"; it does not require problem symmetry to be effective, and it appears to be reasonably easy to program.

Our solution to the problem employs modular associative memories for data and instructions, with associative logic to control the parallel processors.

One programming method employs a binary tree program structure whereby several processors can be working simultaneously on the branches of the tree. The Tag portion of each instruction word shows its position in the tree and permits a simple computation for determining the Tags of the successor, predecessor, and "complementary" instruction words. The instruction words can then be retrieved associatively on the basis of their computed Tags. Other portions of the instruction word include fields for the Status, the Code and the Item.

Input words of data are associated with their instruction words, and new words of data are created with appropriate Tags and marked "Ready." An available processor looks for work to do by interrogating memory for a word in the Ready status. When the processor completes a set of instructions, or is unable to proceed, intermediate results will be stored with appropriate Status indication; the processor then proceeds autonomously to find any other Ready words.

Examples are given illustrating a program including multidirectional, simultaneous, conditional and nonconditional branching in an iterative loop.

Atomic Negative Ions, Enrico Clementi and A. D. McLean, *The Physical Review* **133,** A419-A423 (January 20, 1964).

Results of Hartree-Fock calculations on the ions of Li^-, B^-, C^-, N^-, O^-, F^-, N^{--}, O^{--}, in states of the lowest electronic configuration, along with correlation and relativistic corrections, are given. These data are used to compute electron affinities for the atoms of the first row of the periodic table, and the stabilities of the excited states of the ions relative to the neutral atoms. Computed electron affinities for atoms on which experimental determinations are not available are 0.58 ± 0.05 eV for lithium, 0.3 ± 0.05 eV for boron, and -0.27 ± 0.11 eV for nitrogen. Computed electron affinities for other first row atoms are in agreement with experiment with the exception of oxygen, where the computed value of 1.22 ± 0.14 eV is significantly less than the experimental determination of 1.47 eV. For the first row atoms, no excited states of the ground-state electronic configuration are lower in energy than the neutral atom, although $C^-(^2D)$ is only 0.08 ± 0.05 eV above.

Atomic Negative Ions. Second Period, E. Clementi, A. D. McLean, D. L. Raimondi and M. Yoshimine, *The Physical Review* **133,** A1274-A1279 (March 2, 1964).

Results of Hartree-Fock calculations on the ions Na^-, Al^-, Si^-, P^-, and Cl^- in states of the lowest electronic configuration, along with correlation and relativistic corrections, are given. The data are used to compute electron affinities for the atoms of the second row of the periodic table, and the stability of the excited states of the ions relative to the neutral ground-state atoms. The computed electron affinities for atoms on which experimental determinations are not available are 0.78 eV for Na, 0.52 eV for Al, 1.39 eV for Si, and 0.78 eV for P. The computed electron affinities for S and Cl are 2.12 and 3.56 eV in fair agreement with the experimental values of 2.07 ± 0.07 and 3.613 ± 0.003 eV, respectively. For the second-row negative ions, several excited states are lower in energy than the corresponding ground-state neutral atoms; the computed stabilities for the species $Al^-(^1D)$, $Si^-(^2D)$ and $Si^-(^2P)$ are 0.23, 0.58, and 0.08 eV, respectively. While the ^1D state of P^- is estimated to be very close to that of $P(^4S)$, our estimates are not accurate enough to say definitely whether it is above or below.

Automated Contact Resistance Probe, Morton Antler,* L. V. Auletta and J. Conley, *The Review of Scientific Instruments* **34,** No. 12, 1317-1322 (December, 1963).

A probe is described that will determine (a) contact resistance with continuously increasing pressure from 0 to 1000g., (b) contact resistance as a function of wipe dis-

tance at fixed normal load, and (c) the current voltage properties of films from 0 to 200V. In pressure and voltage modes, specimen positioning is entirely automatic and programmable. The probe locates the test surface on an X-Y plane, goes through the selected mode, and then automatically repositions and repeats the measurement according to test schedule. The wipe mode is performed manually. Resistance, current, voltage, load, wipe distance, and location of the specimen are read out on an oscillographic recorder.

*Present address: Research Division, Burndy Corporation, Norwalk, Connecticut.

Automatic Digital Setup and Scaling of Analog Computers, Henry M. Paynter* and Julian Suez, *ISA Transactions* **3,** No. 1, 55-65 (January, 1964).

Optimal scaling for electronic analog computers can be difficult and tedious. This is especially true when the differential equation to be solved is either non-linear or of fifth or higher order. The present scheme of automated programming of differential equations for analog computers organizes the equations in such a way that chances for programming and scaling errors are minimized. Moreover, it reduces computing time as well as programming effort, thus fostering the optimum utilization of analog computers.

The procedure of automated programming described in this paper involves, first the establishment of the governing differential equations in the standard form by the analog programmer and, second, the automatic digital simulation yielding the numerical solution of these equations for a base case from which the scaling constants and coefficients for the analog computer settings are derived. In addition, all interconnections among the analog components are outputs from the digital printout. Thus the technique employed will ultimately permit the entire task of setup and scaling to be automated by means of a suitable hybrid machine.

*Massachusetts Institute of Technology.

Automatic Mapping System Design, H. F. Dodge,* *Photogrammetric Engineering* **30,** No. 2, 238-242 (March, 1964).

The pressing need for high-speed mapping, particularly by the U. S. military establishment, indicates that greater consideration of automatic mapping system design is required. Digital simulation studies are discussed as very useful tools in photogrammetric system design.

* Present address: Auroutronic Corporation, Reseda, California.

Band Theory of Ferromagnetism, Antiferromagnetism, and Spin Waves, D. C. Mattis, *Journal of Applied Physics* **35,** No. 3 (Part 2), 1085-1086 (March, 1964).

Intra-atomic exchange (Hund's rule mechanism) and Heisenberg nearest-neighbor exchange are examined for their role in the ferromagnetism of metals with degenerate bands. The equations of motion of spin waves valid near $T = 0°K$ are derived, and a number of branches are found. When the equations are solved in the approximation that $k_F \ll$ size of the Brillouin zone, the spin waves all have positive energy, and have wave vectors not exceeding $0.9k_F$ in magnitude. When the electrons approximately half-fill the Brillouin zone, it is possible for some spin waves to have negative energy, and for an antiferromagnetic state to become stable. This is not proved, but indicated on the basis of an earlier calculation that also showed that ferromagnetism is less stable against antiferromagnetism in face-centered cubic materials than in either the simple, or body-centered cubic structures.

Beat Frequencies Between Modes of a Concave-Mirror Optical Resonator, John P. Goldsborough, *Applied Optics* **3,** 267-275 (February, 1964).

The beat frequencies between modes of an optical resonator with concave mirrors have been studied by the photomixing technique. Lasers operating on the 6328 Å He-Ne transition were used. The results agree well with theory. Removal of degeneracy by resonator irregularities and mode repulsion effects have been observed. The technique of partially blocking the external laser beam in order to observe all the beat frequencies is pointed out.

Behavior of CdS Thin Film Transistors, M. G. Miksic, E. S. Schlig and R. R. Haering,* *Solid State Electronics* **7,** 39-48 (January, 1964).

The behavior of a number of experimental CdS thin film transistors has been studied. The fabrication procedure for these devices is discussed and data illustrating the variation of device behavior with temperature and with frequency are presented. It is shown that these observations are in accord with the notion that the carrier mobility as well as the carrier concentration is altered by the gate voltage. All of the devices which were studied exhibit a frequency dependence which can be understood in terms of slow traps. The evidence suggests that these traps are located on the surface of the CdS layer.

* Department of Physics, Waterloo University, Waterloo, Ontario, Canada.

Calculated Diffusion-Controlled Evaporation Rates of Elements from Germanium, G. A. Somorjai, *Transactions of the American Society for Metals* **57,** 26 (1964).

The evaporation rates of many compounds into vacuum were found to be appreciably lower than that of their maximum evaporation rates, calculated from equilibrium vapor pressure measurements. The low evaporation rate is believed due to a rate limiting surface reaction which precedes the desorption step. It is shown that diffusion of the evaporating species to the surface can also be the rate determining step in the evaporation process. The impurity-germanium systems are depicted to demonstrate diffusion governed vaporization. The over-all evaporation rates have been derived and calculated for a number of impurities.

Coupled Biaxial Films, Hsu Chang, *Journal of Applied Physics* **35,** No. 3 (Part 2), 770-771 (March, 1964).

Biaxial films were proposed by Pugh for storage elements of a noncoincident memory. In this paper, it is demonstrated that two identical uniaxial films with their easy axes at a right angle and driven by interposed striplines that carry currents also exhibit biaxial properties.

Current Behavior in a Superconducting Solenoid Prior to and at Breakdown, M. W. Dowley, *Applied Physics Letters* **4,** 41-43 (February 1, 1964).

Evidence for flux jumping in a superconducting solenoid made of Nb:Zr alloy is presented. The flux jump introduces a resistance if sufficient heat is liberated in the jump. The resistance may persist and grow leading to breakdown or else may decay. Evidence for both types of behavior is given in the form of sharp voltage pulses from the secondary of a transformer, the primary of which is in series with the solenoid.

A Delay-Line Push-Down List, P. A. Lord, C. J. Tunis and H. L. Witter, *IEEE Transactions on Electronic Computers* **EC-12,** No. 6, 872-874 (December, 1963).

"List structure" arrangements of information are increasingly being used in digital data-processing applications. A "push-down" list is one manipulated in a last-in, first-out manner. The implementation of such a list structure is possible in a variety of ways. This paper describes one such method which uses a delay line as a storage device.

Differential Pumping of a Narrow Slot, E. Donath, *Transactions, The Tenth National Vacuum Symposium, American Vacuum Society,* (1963).

Theoretical and experimental results on differential pumping of a narrow, rectangular slot are presented. The slot is open to atmosphere at the inlet side, and the variation of end pressure with slot depth is studied. A simple method based on the type of flow occurring in each stage, is given for determining the optimum position of pumps along the length of the slot. With this design precedure pressures on the order of 10^{-6} torr have been achieved at the end of a 12 inch long, 1.6 inch $\times$ 0.007 inch slot.

Diffusion and Solubility of Zinc in Gallium Phosphide Single Crystals,† L. L. Chang and G. L. Pearson,* *Journal of Applied Physics* **35,** No. 2, 374-378 (February, 1964).

Radiotracer Zn^{65} has been diffused into 0.2 ohm-cm sulfur doped GaP single crystals from constant pressure vapor sources. Solid solubilities have been measured at temperatures between 800°C and 1100°C, the diffusion profiles have been obtained and these have been analyzed by the Matano method. Although retrograde solid solubility is expected at higher temperatures, the data below 1100°C are an excellent fit to the relation $C = 2.5 \times 10^{23} \exp(-0.85/kT)$. The diffusion coefficient is found to be concentration dependent. At temperatures below 900°C the diffusion coefficient can be represented by the empirical expression $D = 7.5 \times 10^{-8}\ C^{0.45} \exp(-2.50/kT)$. Above 900°C the profiles are similar to those of Zn in GaAs and the diffusion coefficient varies approximately as the square of the zinc concentration. The results are interpreted and the diffusion mechanism is discussed in terms of parallel-mode diffusion of interstitial and substitutional zinc.

† Work performed at Stanford University.
* Stanford Electronics Laboratory, Stanford University.

Diffusion Problems Related to GaAs Injection Lasers, M. H. Pilkuhn and H. Rupprecht, *Transactions of AIME* **230,** 296 (March, 1964).

p-layers on *n*-type substrates of GaAs were prepared by diffusion of zinc into these substrates. Experimental details about the diffusion technique are presented. It is shown that inhomogeneity in the substrate doping level and crystal structure defects cause nonplanarity in the junction plane. These nonplanarities give rise to high threshold current densities. From incremental sheet-conductivity measurements the zinc profile is derived. Data about surface concentration and gradient of the zinc concentration at the junction are presented. Finally, some results of laser diodes, which were made of wafers with extremely planar diffusion fronts, are discussed.

Dispersion of the Index of Refraction Near the Absorption Edge of Semiconductors, F. Stern, *The Physical Review* **133,** A1653-A1664 (March 16, 1964).

A simple method is used to calculate the contribution of the rapid rise in optical absorption near the absorption edge of semiconductors to the index of refraction near the edge. Other contributions to the index are also estimated. The results give qualitative agreement with the results obtained for PbS by Riedl and Schoolar, and very good agreement with Marple's prism measurements of the index for GaAs. Some applications to injection lasers are discussed. The temperature and pressure dependence of the index of refraction near the absorption edge is estimated, and agrees well with experimental results for GaAs.

Double Monochromator Systems, R. L. Christensen and R. J. Potter, *Applied Optics* **2,** No. 10, 1049-1054 (October, 1963).

A geometrical analysis of image formation in single monochromators is expanded to include the dual monochromator and the tandem monochromator, a system of two single monochromators used in series. The tandem system is useful in measurements of monochromator transmittance and in providing double dispersion. This analysis leads to expressions for the passbands, radiance in the final slit plane, and transmitted flux, as the widths of the intermediate and final slits are varied.

Dynamic Operation of the In-Line Cryotron in Bistable Circuits, A. E. Brennemann, H. Seki and D. P. Seraphim, *Proceedings of the IEEE* **52,** No. 3, 228-238 (March, 1964).

The dynamic operation of the in-line cryotron is tested by performing pulse measurements on individual devices and also by using the devices in free running closed loop oscillators. The signal propagation time around the loop oscillators is slow when compared to the 10 nsec time constants, L/R, that was designed for each stage. The slower propagation time is shown to be associated with the unexpected slow switching time of the in-line cryotron. The oscillator circuit analysis, using the observed cryotron switching times, shows that the maximum obtainable oscillator frequency of 5 Mc/sec can be predicted with reasonable accuracy. The factors that limit the in-line cryotron switching time in a bistable circuit are discussed along with projected cryotron improvements that could lead to bistable circuit time constants of 10 nsec.

Dynamics of Synchronous-Precessing Turborotors, with Particular Reference to Balancing—Part I: Theoretical Foundations, Tung-Men Tang and P. R. Trumpler,* *Journal of Applied Mechanics* **31,** No. 1, 115-122 (March, 1964).

The commonly employed "indifferent equilibrium" postulate is rejected as internally inconsistent, and the dynamics problem is solved by using a system of discrete masses with fixed unbalances arbitrary in magnitude and direction. A method is presented for the calculation of bearing reaction as a function of machine speed including the effect of turbulent-flow damping at disc masses, so-called gyroscopic moments, and bearing oil film and support flexibility. The calculation is particularly adapted to a digital computer program employing successive multiplication of 5 × 5 matrices with complex elements.

* University of Pennsylvania.

The Effect of Crystal Orientation on Ge-GaAs Hetero-Junctions, F. Fang and W. E. Howard, *Journal of Applied Physics* **35,** No. 3 (Part 2), 612-617 (March, 1964).

The electrical characteristics of Ge-GaAs heterojunctions, in particular *n-n* junctions, have been studied experimentally. Barrier voltages were determined from the temperature dependence of reverse current and from capacitance versus voltage. It is found that the barrier voltages depend upon the crystal orientation of the interface. This is seen to imply a corresponding variation of the conduction band discontinuities; namely ΔE_c [111] Ga > ΔE_c [111] As > ΔE_c [110]. The voltage dependence of the reverse current is interpreted in terms of the shift of the Fermi level with respect to the conduction band edge in the accumulation layer. The transient behavior of *n-n* heterojunctions has also been investigated. The time for switching 20 mA is less than 10^{-9} sec, and no storage time is observed.

Effect of Misalignment on a Circular, Externally Pressurized Gas-Lubricated Bearing, L. Licht and R. K. Kaul, *Journal of Applied Mechanics* **31,** No. 1, 141-143 (March, 1964).

Pressurized sliders find frequent application in magnetic and optical recording systems, and the prediction of their dynamic response is of considerable importance. The present paper furnishes means of estimating effects of misalignment of externally pressurized bearings and of predicting the dynamic response from static bearing characteristics.

The Effects of Particle Orientation on Interactions in Magnetic Recording Tapes, R. A. Cummings* and C. D. Mee, *Proceedings of the INTERMAG Conference* **T-159,** 6-3-1 to 6-3-4 (April, 1964).

High frequency ac bias recording is a modification of the anhysteretic magnetization process. This process is analyzed for magnetic tapes consisting of assemblies of elongated single-domain magnetic particles taking account of the relative orientations between the axes of the particles and the magnetic fields acting on them. The angular variation of initial anhysteretic susceptibility and the anhysteretic magnetization curves are calculated for oriented particle arrays giving good agreement with measurements on some recording tapes.

• Singermetrics, South Norwalk, Connecticut.

Effects of Radiation Forces on the Attitude of an Artificial Earth Satellite,† T. F. Clancy and T. P. Mitchell,* *AIAA Journal* **2,** No. 3, 517-524 (March, 1964).

The motion of an artificial earth satellite about its center of mass as a result of radiation forces is investigated. The satellite is assumed to be symmetrical, both geometrically and dynamically. The sources of radiation considered are: direct solar radiation, solar radiation reflected by the earth and its atmosphere, and direct radiation from the earth. The radiation torques cause an unperturbed Euler-Poinsot motion of the satellite axis of symmetry about its angular momentum vector. The satellite's angular momentum vector, while remaining practically constant in magnitude, precesses and nutates relative to inertial space.

† This work was carried out while the author was a student at Cornell University.
* Assistant Professor, Engineering Mechanics Department, Cornell University.

Electrodeposited Palladium as a Low-Energy Circuit Contact Coating, G. D. Fatzer, *Plating* **50,** No. 11, 1000-1005 (November, 1963).

Porosities of thin palladium electrodeposits, obtained by the insoluble anode process and to be used for electrical contact applications, are determined. The various palladium deposition processes are compared using porosity as the criterion. Minimum porosity is shown to be achieved using the insoluble anode process. Pore-free palladium films 1.25μ thick can be deposited on copper substrates from a palladosammine chloride solution over a wide range of palladium concentrations. The palladium films have a hardness of 370-390 $KHN_{(25g)}$ and show good corrosion resistance to H_2S.

Electron Beam Recording of Digital Information, R. F. M. Thornley, A. V. Brown and A. J. Speth, *IEEE Transactions on Electronic Computers* **EC-13,** No. 1, 36-40 (February, 1964).

An electron recording system for a high density read-only photographic memory has been developed. The information has been recorded at speeds up to 10^6 bits/sec with a storage density of 10^6 bits/cm^2. After processing, the information can be read back optically at 10^6 bits/sec.

The high recording speed given by the electron beam technique makes it possible to extend the use of photographic memories to systems requiring frequent updating or systems with capacities of more than 10^8 bits.

Electron Spin Resonance of Cyclopentadienyl, P. J. Zandstra, *The Journal of Chemical Physics* **40,** 612 (January, 1964).

Pyrolysis of a molecular beam of dicyclopentadienyl iron (ferrocene) leads to formation of cyclopentadienyl radicals. The observed electron spin resonance absorption spectrum consists of six equally spaced lines with a splitting of

5.98 G. The intensity ratio is 1:5:10:10:5:1, characteristic for five equivalent protons. Averaging over the two conformations takes place leading to the equivalence of the five protons. Pyrolysis of azobenzene ($C_6H_5NNC_6H_5$) leads to the same radical.

Electron Spin Resonance Studies of Alkali Metal Trapping Sites in Solid Rare Gases, J. P. Goldsborough and T. R. Koehler, *The Physical Review* **133,** A135-A140 (January 6, 1964).

Measurements of the hyperfine structure of alkali metals trapped in solid rare gases have been made. When the zero-field hyperfine splitting values obtained in the solid matrix are compared with the free atomic values, it is found that they fall into two groups. In one group the hyperfine values are within a few percent of the free atomic value. The other group has hyperfine values smaller than the free atomic value by 10 to 30%. It has been found that the latter trapping sites occur only when the sample is exposed to room temperature infrared radiation during deposition on the liquid helium cooled finger. The effects of annealing and concentration have also been studied. The annealing experiments show that once the shifted sites are formed they are very stable.

EPR of Exchange-Coupled Pairs of Eu^{2+} in CaO and SrO,† B. A. Calhoun and J. Overmeyer, *Journal of Applied Physics* **35,** No. 3 (Part 2), 989-990 (March, 1964).

The EPR spectra of isolated Eu^{2+} ions have been studied in crystals of CaO and SrO. In SrO, there is no crystal field splitting of the $^8S_{7/2}$ level of the Eu^{2+}. The g values and hyperfine constants are the same in both crystals. Crystals of CaO and SrO containing 1%-2% Eu exhibit in addition a large number of weak lines at both lower and higher fields than the single ion spectra observed in more lightly doped crystals. These resonances arise from coupled pairs of Eu^{2+} ions, and their analysis provides direct information about the exchange interactions between the Eu^{2+} ions. The temperature dependence of these intensities shows that the nearest neighbor exchange interaction J_{nn} is ferromagnetic and its magnitude is approximately 1°. In the [100] direction, some of the resonances due to next-nearest neighbor pairs have been identified. This exchange interaction J_{nnn} is very small, less than 0.1°. Its sign cannot be determined from the temperature dependence of the intensities of the resonances. These values for the exchange interactions are in agreement with those inferred from the magnetic properties of the europium chalcogenides.

† This work supported in part by the U. S. Air Force Office of Scientific Research.

Evaluation of the Ginzburg-Landau-Abrikosov-Gorkov Parameters from a Nonlocal, Nonlinear Theoretical Model, A. M. Toxen, *The Physical Review* **133,** A1218-A1221 (March 2, 1964).

Expressions for the Ginzburg-Landau-Abrikosov-Gorkov (GLAG) parameters such as the weak-field penetration depth δ_0, the dimensionless parameter κ, and the range of order parameter δ_0/κ have been obtained from a simple, nonlocal, nonlinear theoretical model previously used to calculate the critical fields of superconducting films. We have shown that in the local limit, these expressions yield results which are in quite good agreement with those obtained by other techniques. We have also obtained simple expressions for these parameters which are valid in the thin film limit. From these limiting formulas, it is apparent that κ can get large in thin films, and it is estimated that κ exceeds the critical value of $1/\sqrt{2}$ in indium films somewhat thinner than 1000 Å. We also conclude that in the thin limit, one would expect the order parameter to be nearly constant across the film thickness.

Exact Solution of the Ginzburg-Landau Equations for Slabs in Tangential Magnetic Fields, P. M. Marcus, *Reviews of Modern Physics* **36,** No. 1 (Part 1), 294-299 (January, 1964).

Exact solution of the one-dimensional Ginzberg-Landau equations for slabs of both small and large kappa materials leads to detailed description of the effect of a tangential external field. Typical Type II behavior is found for thick slabs of large kappa material with a (first-order) phase transition at a lower critical field to a second superconducting phase, and a (second-order) phase transition to the normal state at an upper critical field. The solution in the high-field phase consists of a superconducting core surrounded by nearly normal material, and thus resembles the intermediate state more than the mixed state. A sequence of solutions in which the order oscillates about zero is shown to exist, and can be locally stable, but the state of lowest free energy is shown to be always nodeless.

The Fabrication of Thin Film Circuits, A. E. Lessor, L. I. Maissel and R. E. Thun, *Semiconductor Products and Solid State Technology* (in two parts) Part 1: **7,** No. 3, 28 (March, 1964); Part 2: **7,** No. 4, 28 (April, 1964).

The various methods of depositing thin-film circuits are surveyed, with special emphasis on vacuum evaporation and cathode sputtering. Included is a discussion of techniques to control such parameters as rate, substrate temperature, film thickness, and pattern configuration which influence the structural and electronic film properties. Following a description of the characteristic properties of film resistors and capacitors, their integration into complex circuits and electronic networks is treated. Some solutions to testing and packaging such circuits and circuit assemblies are presented.

Ferromagnetic Europium Compounds, T. R. McGuire and M. W. Shafer, *Journal of Applied Physics* **35,** No. 3 (Part 2), 984-988 (March, 1964).

Ferromagnetism has been found in several divalent europium compounds. Some of these materials are particularly simple in both crystal and magnetic structure and are ideal for experimental and theoretical study. The materials we have investigated can be divided into three groups, europium chalcogenides, europium halogens, and europium silicates. Magnetic information on these compounds are summarized and theoretical results reviewed.

The europium chalcogenide series all have the rocksalt structure, the oxide, sulfide, and selenide being ferromagnetic, and it is on these materials that the most work has been done. This is especially true of EuS where detailed moment, specific heat, and nuclear magnetic resonance measure-

ments are available. Theoretical analysis indicates that there is positive exchange between nearest-neighbor europium atoms which decreases with increasing atom spacings. There is also a weaker negative superexchange via the anions in these compounds which is responsible for antiferromagnetism in EuTe. The EuTe magnetic ordering has been studied by neutron diffraction at Brookhaven and the sublattice magnetization-temperature behavior is found to be somewhat anomalous. EuSe is ferromagnetic but reveals low-field magnetization curves that have an unusual shape. In view of this, EuS seems to be the simplest of the group so that fundamental parameters obtained from analyzing the data are probably the most reliable.

In the halogen group, EuI_2 appears to be ferromagnetic while EuF_2 is apparently antiferromagnetic. The latter behavior is somewhat unexpected from interatomic distance consideration which hold for the chalcogenides. Of three silicates prepared, two were ferromagnetic. The most interesting was Eu_2SiO_4 which was obtained as transparent single crystals. Magneto-optical studies show this compound to have a Verdet constant higher than any other previously reported.

Ferrimagnetic Resonance Relaxation in Rare-Earth Iron Garnets, P. E. Seiden, *The Physical Review* **133,** A728-A736 (February 3, 1964).

A quantitative analysis has been made of the ferrimagnetic resonance relaxation in rare-earth iron garnets. The data considered consist of measurements of the ferrimagnetic resonance linewidth of yttrium iron garnet substituted with neodymium, samarium, dysprosium, holmium, erbium, and ytterbium taken from 4.2°K to just below the Curie point, as well as data of other investigators for terbium and thulium. The data are conveniently divided into the two groups of odd and even electron ions. The ions in each group behave in a similar manner, the only exceptions being thulium and ytterbium. It is assumed that all the relaxation occurs through the strongly relaxing rare earth ions but we find that both the "fast relaxation" theory of de Gennes, Kittel, and Portis and the "slow relaxation" theory of Clogston, Van Vleck and Orbach fail to provide agreement with experiment. We have, however, formulated an empirical relation containing a relaxation term of the "slow relaxation" type that provides an excellent fit to the data when one regards the relaxation of the rare earth as being the familiar one-ion spin-lattice relaxation due to the direct (one phonon) and Orbach (two phonon) processes. The observed temperature dependence of the linewidth is satisfactorily accounted for if one assumes the direct process for the odd electron ions and the Orbach process for the even electron ions. In the case of thulium, one finds it necessary to assume the direct process, and for ytterbium one finds evidence for both processes, the direct process being dominant at low temperatures and the Orbach process dominant at high temperatures. The analysis allows evaluation of the iron-rare-earth exchange frequency and the rare-earth relaxation parameters. The exchange frequencies are found to be in good agreement with the values obtained by other investigators. In the one case where independent relaxation time measurements exist, that of samarium iron garnet, the behavior we find from the linewidth measurements agrees with that found by Caspari et al. by γ - γ correlation experiments. The frequency dependence predicted by the empirical relation is also in accord with experiment and a quantitative calculation of the frequency dependence of the peak value of the linewidth and the temperature of the linewidth peak yields excellent agreement with the data of Dillon for terbium.

Ferromagnetism in Rare-Earth Group Va and VIa Compounds with Th_3P_4 Structure, F. Holtzberg, T. R. McGuire, S. Methfessel and J. C. Suits, *Journal of Applied Physics* **35,** No. 3 (Part 2), 1033-1038 (March, 1964).

The bcc structure $I\bar{4}3d$-T_d^6 (Th_3P_4) occurs as a defect structure in 2:3 compounds of rare-earth elements with S, Se, and Te, or as an inverted structure in 4:3 compounds with group Va elements. The structural, electric, and magnetic properties of the metallic 4:3 compounds and the 2:3 rare-earth semiconductors have been investigated with specific reference to gadolinium, for which the S ground state gives the minimum crystal field effect.

Gd_4Bi_3 and Gd_4Sb_3 are both ferromagnetic with a saturation magnetization obeying the spin-wave $T^{3/2}$ law up to 0.8 of the Curie temperature. The Curie temperature T_c varies in the solid solution system Gd_4Sb_3-Gd_4Bi_3 with composition from 260 to 340°K. The semiconducting compound Gd_2Se_3 ($\rho_{RT} = 3\ \Omega$ cm) has been found to be antiferromagnetic below $T_N = 6$°K. Solution of Gd in the holes of the defect Th_3P_4 structure decreases the electrical resistivity without a measurable variation of lattice constant ($\alpha_0 = 8.718$ Å). With increasing conductivity the material changes from antiferromagnetic to ferromagnetic. At the composition $Gd_{2.1}Se_{2.9}$ the Curie temperature is $T_c = 80$°K with $\rho_{RT} = 1.4 \times 10^{-5}$ Ω cm. The relation between Curie temperature and the electrical resistivity has been examined by introducing the same spin concentration into Gd_2Se_3 by Eu^{2+} doping. The semiconductor $Eu_{0.5}Gd_{1.6}Se_{2.9}$ is paramagnetic. However, $Y_{0.5}Gd_{1.6}Se_{2.9}$ has low resistivity and is ferromagnetic below $T_c = 47$°K.

The Field-Effect Interface Conductance in Ge-GaAs *n-n* Heterojunctions, L. Esaki, W. E. Howard and J. Heer, *Applied Physics Letters* **4,** No. 1, 3-4 (January 1, 1964).

The field-effect interface conductance of the accumulation layer has been investigated in the Ge side of Ge-GaAs *n-n* heterojunctions with the dc and ac techniques, and the effective surface mobility has been deduced from the surface conductance together with the junction capacitance measurement. The results indicate the constant surface mobility within the present experimental error, which might cast some doubts on the validity of an assumption of random surface scattering.

Free Energy of Composite Wires in the Superconducting State, D. P. Seraphim, F. M. d'Heurle and W. R. Heller, *Reviews of Modern Physics* **36,** No. 1 (Part 1), 323-327 (January, 1964).

Magnetic moment measurements have been made on composite wires in the superconducting state as a function of temperature and state of subdivision. Among metals we have studied are lead-aluminum and lead-bismuth-aluminum. The metal portions ordinarily superconducting are of the order of the coherence length or much less in diameter. Wires of aluminum containing about 1% by volume of lead, for example, show an initial diamagnetic susceptibility corresponding to almost complete exclusion of flux well above the critical temperature of Al. The curves of magnetic moment vs field are integrated directly to give free energy curves. The curve of free energy vs temperature can be interpreted in terms of an interaction between the two metals which allows the aluminum to have superconducting

order in a temperature range normally not accessible. Using a simplified model of the composite, it is possible to apply the Ginzburg-Landau equations and to evaluate the temperature-dependence of the free energy of superconducting aluminum above its normal transition temperature.

Grundlagen, Bauelemente und Messtechnik der Nanosekunden-Impulstechnik (Fundamentals, components and measuring techniques of nanosecond pulse techniques), A. P. Speiser, *Bulletin des Schweizerischen Elektrotechnischen Vereins (SEV)* **55,** No. 3, 90-96 (February 8, 1964).

Nanosecond pulse techniques refer to circuits that produce and handle pulses whose rise times are a few nanoseconds. The work with such circuits is characterized by the fact that connections as short as 2 inches cause a noticeable propagation delay. The important components are diodes and transistors. The measuring technique is dominated by sampling oscilloscopes.

Heat Capacity of the Exchange Bath in Solid He^3, R. L. Garwin and H. A. Reich, *Physical Review Letters* **12,** 354-357 (March 30, 1964).

The ratio of the exchange specific heat to the Zeeman specific heat was measured in solid, β-phase, He^3 by means of the spin echo technique. The ratio was found to be $\approx$ 350, a factor 4000 larger than predicted. This discrepancy remains unexplained.

Here Are Five Practical Epoxy Casting Formulations, Richard N. Wood, *Plastics Technology* **10,** No. 2, 37-38 (February, 1964).

In no area is the versatility of epoxies more evident than in formulating casting resins. Properties and characteristics of casting-type resins can be varied so much, in fact, that compounders frequently have more formulations than they can ever use. However, when practical applications must be made, a few basic formulations can usually be counted upon. The following systems fall into this category: (1) low viscosity formula, (2) dimensionally stable formula, (3) high-temperature resistance formula, (4) flexibility and resilience formula, and (5) general-purpose formula. Compositions and physical properties of the five epoxy formulations are presented in a comparative table of data.

High-Energy Light Emission from Junctions in $GaAs_xP_{1-x}$ Diodes, A. Ainslie, M. Pilkuhn and H. Rupprecht, *Journal of Applied Physics* **35,** No. 1, 105-107 (January, 1964).

Spontaneous and stimulated emission from junctions in diodes made of silicon-doped, melt-grown $GaAs_xP_{1-x}$ alloys have been studied. Variations of the emission spectra as a function of current and of composition ranging up to 40 mole % GaP were examined both at room temperature and 77°K.

Hilbert Space with Non-Associative Scalars I, H. H. Goldstine and L. P. Horwitz, *Mathematische Annalen* **154,** 1 (February, 1964).

Some properties of a Hilbert space in which Cayley numbers are admitted as multipliers are discussed. It is shown that the usual spectral resolution for Hermitian operators is valid, and with its help the connection between a ring of hypercomplex operators generated by the Cayley numbers and the geometrical structure of the Hilbert space is established.

How Temperature Variations Affect Accuracy When Machining Aluminum, D. Weisman, *The Tool and Manufacturing Engineer* **52,** No. 2, 91 (February, 1964).

Variables such as the ambient temperature range, workpiece temperature and gage temperature all influence the ultimate accuracy of machined parts. When the workpiece is of aluminum, special measurement problems are encountered because the thermal expansion of aluminum is twice that of steel.

IBM Develops Fly's Eye Lens Technique For Generating Semiconductor Photo Masks, W. E. Rudge, W. E. Harding and W. E. Mutter, *Reproduction Methods* **4,** No. 3, 33 (March, 1964).

In the development and fabrication of transistors and other semiconductor devices, an immediate source of photographic masks is a tremendous asset. The fly's eye lens provides a novel method of producing masks of high quality and excellent mask-to-mask registration. A 500-to-1 reduction is made in one step through an array of plastic lenses, giving resolution of 400 lines per/mm. Usable lines 0.1 mil wide can be made. A set of photographic masks can be produced in two hours.

IBM 7340 Hypertape Drive, R. A. Barbeau and J. I. Aweida, *AFIPS Conference Proceedings* **24,** Fall Joint Computer Conference, 591-602 (1963).

The input-output demands of some IBM computer systems require the increased data rate, high reliability, and reduced system-access time that are provided in the IBM 7340 Hypertape Drive. It is capable of an instantaneous data rate of 170,000 eight-bit alphanumeric characters or 340,000 packed characters per second, with an access time as short as 4.2 msec.

Tape motion is controlled by a single clutched capstan. The recording surface of the tape is protected by the elimination of pinch rollers and other driving surfaces. Acceleration is achieved from the back surface of the tape. With the capstan drive mechanism, start times are 2.5 msec, with less than 5% overshoot. The fast start-stop times are obtained, in part, by the action of moving-coil actuators. Minimum overshoot resulted from a unique capstan design which includes a fluid coupling.

The motion of tape reels in the Hypertape Drive is under continuous control by detecting the location and velocity of the tape loop in the column with a correlated control of the power to the drive motor. Loop location is determined by a capacitive sensing method.

Ten parallel information tracks can be recorded across the inch-wide tape, using a two-gap write-read head. The IBM

7640 Hypertape Control Units contain error detection and correction circuitry. Corrections are made without program interruptions.

Incentive Contracts and Price Differential Acceptance Tests, B. J. Flehinger and J. M. Miller, *Journal of the American Statistical Association* **39,** No. 305, 149-159 (March, 1964).

It may be economically advantageous to both consumer and producer to enter into an incentive type contract in which the price paid for a product depends upon the outcome of an acceptance test. If no test is performed, a product of some minimum quality is produced and the consumer suffers a considerable penalty. The outcome of the test will reflect, to some degree, the quality of the product. If the consumer agrees to pay a premium dependent upon the outcome, the producer will be motivated to invest money in improving his product and both parties may expect to profit from the arrangement.

This paper constitutes an unconventional approach to acceptance testing, in which the test is viewed not as a procedure to obtain information but rather as motivation toward product improvement. Admissible strategies are defined and their properties are studied. An application to repairable systems is considered in detail.

Der Einfluss von Wirbelstroemen auf den Induktivitaets —und Widerstandsbeleg unsymmetrischer Parallelbandleitungen (The influence of eddy currents on the inductive and ohmic layers of unsymmetrical parallel striplines), Wilhelm Jutzi, *Archiv der Elektrischen Uebertragung* **17,** No. 9, 420-428 (1963).

A rigorous solution of the boundary problem on unsymmetrical parallel striplines for determining the frequency dependence of the inductive and ohmic layers seems to be rather unsuited to yield numerical results even with an electronic computer. Therefore, an approximation method is described which is based on an expansion of the method of substrips for determining capacitances.

Influence of Oxygen on the Surface Mobility of Tin Atoms in Thin Films, H. L. Caswell and Y. Budo, *Journal of Applied Physics* **35,** No. 3 (Part 1), 644-647 (March, 1964).

Tin films less than 800 Å in thickness deposited on 78°K substrates were found to be continuous at low temperatures but to agglomerate into discontinuous islands upon warming to room temperature. Any stage in the agglomeration process could be stabilized by admitting oxygen at a pressure of 10^{-4} Torr and warming the film to room temperature in the presence of oxygen. Electrical resistance data indicate the surface mobility of the tin is reduced by the formation of a surface oxide one to two monolayers in thickness and that there is no appreciable diffusion of oxygen into the bulk of the film material.

Instrument for Continuous High Resolution Measurement of Changes in the Velocity of Ultrasound, R. J. Blume,* *The Review of Scientific Instruments* **34,** 1400-1407 (December, 1963).

The frequency of the "reference" oscillator in a coherent pulse echo apparatus is phase-locked to the spacing in time of the acoustic echoes. A change in echo spacing is thereby converted to the same fractional change of oscillator frequency, which is measured continuously. Echo spacing changes of 2 to 3 parts in 10^8 have been resolved at 12 Mc/sec. The gated AFC circuit which controls the reference oscillator derives its error voltage from a phase-detected echo. The error voltage is zero when the echo is in quadrature with the reference. When the echo spacing changes, the AFC shifts the reference frequency to preserve the quadrature condition. The system is largely insensitive to changes of echo amplitude because such changes do not affect the quadrature condition. The attainable accuracy is set mainly by the temperature stability of the sample. There is a detailed discussion of circuitry, performance, and suggested refinements.

* Present address: Physics Department, Yale University.

Invariant and Reducing Subalgebras of Measure Preserving Transformations, Roy Adler, *Transactions of The American Mathematical Society* **110,** No. 2, 350-360 (February, 1964).

In this paper the lattice of invariant subalgebras of a measure algebra is introduced as a spatial isomorphism invariant for measure preserving transformations.

Light Emission from $GaAs_xP_{1-x}$ Diodes, M. H. Pilkuhn and H. Rupprecht, *Transactions of AIME* **230,** 282 (March, 1964).

The junction luminescence of $GaAs_xP_{1-x}$ diodes containing up to 47% GaP was studied. Diodes were prepared by diffusing zinc into *n*-type material which was either boat- or vapor-grown. Observations concerning the energy and the line shape of the spontaneous emission are presented and discussed; in particular the influence of inhomogeneous phosphorus distribution is considered. The role of reabsorption of the junction radiation is pointed out. With increasing current, the peak emission shifts to higher energy. This is also true in cases where slow line narrowing occurs simultaneously. The length dependence of the threshold current density for lasing at 77°K was examined for lasers made from the same material. It was found that longer lasers have lower threshold current densities. Estimates of the characteristic laser losses are given. Data concerning the range of GaP concentration in which stimulated emission was observed are presented.

Magnetization of Permalloy at Low Temperatures, B. E. Argyle and S. H. Charap, *Journal of Applied Physics* **35,** No. 3 (Part 2), 802-803 (March, 1964).

Pyromagnetic measurements of the magnetization of a single-crystal sphere of Permalloy (79.65 Ni-20.35 Fe by weight) in the range 4.2°-100°K and with applied fields of 4, 9, and 14 kOe parallel to the [111] crystal axis are reported and interpreted in terms of spin-wave theory. The spin-wave energy gap obeys the theoretical expression in terms of internal applied field, magnetocrystalline anisotropy field (negligible), and average spin-wave demagnetizing field. The coefficients appropriate to zero gap are $C = (7.6 \pm 0.1) \times 10^{-6}$ deg$^{-3/2}$ for the $T^{3/2}$ term and $D/C \leq \pm 0.2 \times 10^{-3}$ deg^{-1} for the $T^{5/2}$ term. The analysis of the data is made using a new graphical method which displays visually the quality of fit to the theory. The C

value implies $(JS)_{eff}/k_B = 134°K$ in good agreement with independent determinations of the spin-wave dispersion parameter.

Magnetization Reversal in Weak Ferromagnets, R. J. Joenk, *Journal of Applied Physics* **35,** No. 3 (Part 2), 919-920 (March, 1964).

Reversal of the net ferromagnetic moment in an antiferromagnet exhibiting weak ferromagnetism would appear qualitatively to require only small angle rotation of the sublattice moments. However, consideration of the canting mechanism responsible for the weak ferromagnetism shows that it is asymmetric in a way which requires full 180° reversal of the sublattice moments, i.e., $\mathbf{M}_1 \times \mathbf{M}_2$ retains the same direction in space. This is true for both the Dzialoshinsky-Moriya and single-ion anisotropy canting mechanisms. The critical values of the applied field for reversal of the magnetization and the corresponding initial modes of deviation from equilibrium have been calculated for single-domain particles of antiferromagnetic material having either type of weak ferromagnetic moment. Of the four modes found, two have extremely high critical fields since they involve rotation in opposition of the sublattice moments at the expense of exchange energy. The two reversal modes of interest are (initially) rotations of the $\mathbf{M}_i$ about axes parallel and perpendicular to the particle axis, principally at the expense of anisotropy energy. If the initial character of the motion is assumed to persist, the mode $\Omega_\perp$ would be a 180° rotation of $\mathbf{m} \equiv \mathbf{M}_1 + \mathbf{M}_2$ and $\mathbf{l} \equiv \mathbf{M}_1 - \mathbf{M}_2$ in the plane of the $\mathbf{M}_i$ and the particle axis. The mode $\Omega_\parallel$ would be a 180° rotation of $\mathbf{l}$ in the plane perpendicular to the particle axis while simultaneously $\mathbf{m}$ decreases to zero and then grows to equilibrium value in the opposite direction along the particle axis such that $\mathbf{l}^2 + \mathbf{m}^2 =$ constant. The critical fields for these two modes are given by the zero-frequency limits of the dynamic resonance equations as pointed out by Brown. In general, the smallest critical fields will be found for the $\Omega_\perp$ mode in Dzialoshinsky-Moriya type weak ferromagnets with small, but finite, basal plane anisotropy. The lowest $|H_c|$ calculated is 40 Oe for αFe_2O_3.

Many-Parameter Alternant Molecular Orbital Calculations for Large Cyclic Systems with Closed-Shell Structure, J. D. Swalen and J. De Heer,* *The Journal of Chemical Physics* **40,** 378-384 (January, 1964).

Computer calculations of the energies for various ring systems with closed-shell structure have been carried out within the framework of the many-parameter alternant molecular orbital method. A significant improvement is obtained over the corresponding single-parameter results. Since the explicit energy minimizations are rather time consuming, some semi-empirical relations between the relevant parameters are also discussed.

* Chemistry Department, University of Colorado, Boulder, Colorado.

Mechanical Resonant Frequency of Semiconductor Diodes, H. C. Kammerer, *Electronic Products* **6,** No. 8 (Part 1), 32 (January, 1964).

One method of determining the resonant frequency characteristics of conventional glass-body diodes is described. Data is provided on the dynamic response of the diode to impact shocks and problems associated with ultrasonic cleaning during circuit card fabrication.

MICR—An Analysis, J. L. Morton, *Paper Mill News* **87,** No. 10, 11-12 (March, 1964).

A simple explanation of the American Bankers Association Magnetic Ink Character Recognition program is presented. Particular attention is directed toward the types of paper finish necessary for good printing of magnetic characters. Some problems of the manufacturers of the ink and of the machines used in handling bank checks are discussed.

Mn^{55} Nuclear Magnetic Resonance in Antiferromagnetic $RbMnF_3$, A. J. Heeger and D. T. Teaney, *Journal of Applied Physics* **35,** No. 3 (Part 2), 846-847 (March, 1964).

The observation and study of the Mn^{55} nuclear magnetic resonance in antiferromagnetic $RbMnF_3$ at low temperatures are reported. The direct detection is possible because of a large enhancement of the signal from one of the NMR modes in a low anisotropy antiferromagnet above the critical field for spin flopping. Large frequency pulling effects are observed, and found to be in excellent quantitative agreement with theory. The unpulled NMR frequency has been determined as 687 Mc/sec at 2°K, and the corresponding linewidth is 60 kc/sec. An anomalous increase in linewidth with decreasing field and temperature is described.

A Modified Holland Machine, W. T. Comfort, *AFIPS Conference Proceedings,* Fall Joint Computer Conference, **24,** 481-488 (1963).

A highly parallel machine is a type of multiprocessing system. A parallel-network computer is a type of highly parallel machine. In 1958 Dr. John Holland proposed a parallel-network computer with some unique concepts of instruction sequencing and data accessing, and featuring decentralized control. This paper discusses a modified version of his machine.

The Holland machine is characterized by two significant problems—the complex programming involved and the prodigious amounts of hardware required. The machine described herein proposes to ease the programming and hardware problems without sacrificing the unique computing-power capabilities of the Holland machine.

Some of the organizational variables which require additional study are indicated as a possible direction for future work.

New Ferromagnetic 5:2 Compounds in the Rare-Earth-Palladium Systems, A. E. Berkowitz, F. Holtzberg and S. Methfessel, *Journal of Applied Physics* **35,** No. 3 (Part 2), 1030-1031 (March, 1964).

Gd_5Pd_2 is ferromagnetic below 335°K. The isostructural $Tb_{5.10}Pd_{1.90}$, $Dy_{5.07}Pd_{1.93}$, and $Ho_{5.04}Pd_{1.96}$ have paramagnetic metamagnetic transitions at 62, 41, and 27°K, respectively, and become ferromagnetic at lower temperatures with extremely high hysteresis. Energy products $(\mathbf{B}\times\mathbf{H})_{max} = 20$ to 26×10^6 GOe at 4.2°K have been observed.

A New Heat-Developable Photographic Material, A. H. Sporer, *Photographic Science and Engineering* **8,** 35-43 (January-February, 1964).

The photographic system described is based upon acid catalysis of the aldol condensation of polymethylisopropenyl

ketone to form color bodies. Light absorbed in this photographic material forms catalytic quantities of acid which on heating causes color formation in the irradiated area. Because light is used only to form the catalyst, the over-all quantum yield is higher than unity.

The photographic material is heat-developable and fixable and photographically faster than presently available dry photographic systems. Although the initial films reported here have toxicity problems, it has been demonstrated that a nontoxic film material can be developed which retains the present characteristics of dry (heat) development, but requires a wash for fixing. The present film speeds are about six times faster than diazo-type film speeds and it appears possible to increase this speed 25-fold.

Nuclear Magnetic Relaxation in NaCl at High Temperatures, Maurice Eisenstadt,* *The Physical Review,* **133,** A191-A197 (January 6, 1964).

Measurements of T_1 and T_2, the spin-lattice and spin-spin relaxation times, are reported for Na^{23} and Cl^{35} nuclei in NaCl from room temperature to the melting point. For single-crystal samples below 700°K, T_1 is due to quadrupolar interactions of the nuclei with lattice vibrations and diffusing vacancies, and T_2 arises from the dipolar interaction between nuclei. A jump frequency for positive ion vacancy motion of 4×10^7 sec^{-1} at 510°K is obtained, in good agreement with conductivity measurements. At higher temperatures a number of anomalous features appear and possible explanations are discussed.

* Present address: Columbia University, Hudson Laboratories, Dobbs Ferry, New York.

Nuclear Magnetic Resonance of Gd^{155} and Gd^{157} in the Cubic Ferromagnet GdN,† E. L. Boyd and R. J. Gambino, *Physical Review Letters* **12,** 20-23 (January 6, 1964).

The observation of the nuclear resonance of the two naturally occurring isotopes of gadolinium which have a nuclear moment is reported.

† This work as supported in part by the U. S. Air Force Office of Scientific Research.

Nuclear Magnetic Resonance in Solid He^3—The Exchange Bath, Richard L. Garwin and Andre Landesman,* *The Physical Review* **133,** A1503-A1514 (March 16, 1964).

We have performed spin-echo experiments on β-phase He^3 and have measured the exchange interaction J between He^3 atoms in a consistent way, both by the "exchange narrowing" of the line (exchange lengthening of T_2) and by the strong reduction of T_1 at low magnetic fields ($\gamma H_0 \approx J$). J is found to increase very rapidly with *increasing* molar volume, ranging from less than 20 kc/sec at a lattice constant of 3.4 Å to 90 kc/sec at 3.5 Å, and to about 300 kc/sec at 3.6 Å. These exchange interactions are much too small to account for the "departure from the Curie law" found by Adams, Meyer, and Fairbank. It is shown that the susceptibility is, in fact, "Curie law" (in their temperature range) and we believe that they were reporting—as a susceptibility anomaly—the effect of a long exchange bath-lattice relaxation time (observed for the first time in the present experiment). This exchange-lattice relaxation time varies as $T^{-n}(7 < n < 11)$ and is $\approx$ 100 sec at 1°K for β-phase He^3 of 3.5 Å lattice constant. The results for the exchange-lattice-relaxation time are compared with a modification of a theory by Griffiths. A major mystery remains—the exchange-bath heat capacity as measured by the spin-echo method exceeds the calculated value by $> 10^3$. The exchange interaction is discussed and compared with the prediction of Saunders and others.

* Centre d'Etudes Nucleaires, Saclay, France.

On Ianov's Program Schemata, J. D. Rutledge, *Journal of the Association for Computing Machinery* **11,** No. 1, 1-9 (January, 1964).

Iu. I. Ianov has defined a formal abstraction of the notion of program which represents the sequential and control properties of a program but suppresses the details of the operations. The present paper is intended, first as an exposition of Ianov's results and simplification of his method, and second to point out certain generalizations and extensions of it. We define a somewhat generalized version of the notion of schema, in a language similar to that used in finite automata theory, and present a simple algorithm for the equivalence problem solved by Ianov. We also point out that the same problem for an extended notion of schema, considered rather briefly by Ianov, is just the equivalence problem for finite automata. A simple procedure for generating all schemata equivalent to a given schema is also indicated.

On the Propagation of Pressure Pulses in Circular Elastic Rods, R. K. Kaul, *Zeitschrift für Angewandte Mathematik und Physik* **14,** No. 6, 704-713 (December, 1963).

In the present paper, for studying the propagation of a pressure pulse in a semi-infinite circular elastic rod, use is made of a system of one-dimensional equations of motion which take into account the coupling between longitudinal and radial modes of axially symmetric vibration of elastic rods. Using integral-transforms, the solution is obtained in terms of Fourier integrals which are then analyzed to determine the response at the leading wave front and at the head of the pulse.

Optimum Control of Distributed Parameter Systems, P. K. C. Wang and F. Tung,* *Journal of Basic Engineering* **86,** 67-79 (March, 1964).

This paper presents a general discussion of the optimum control of distributed parameter dynamical systems. The main areas of discussion are: (a) the mathematical description of distributed parameter systems, (b) the controllability and observability of these systems, (c) the formulation of optimum control problems and the derivation of a maximum principle for a particular class of systems, and (d) the problems associated with approximating distributed systems by discretization. In order to illustrate the applicability of certain general results and manifest some of the properties which are intrinsic to distributed systems,

specific results are obtained for a simple, one-dimensional linear diffusion process.

* Present address: Lockheed Missile and Space Company, Palo Alto, California.

Order-Disorder Transitions in Biocolloids, Warner L. Peticolas, *Journal of Chemical Physics* **40,** 1463-1475 (March, 1964).

The author's theory of order-disorder transitions in associative colloids (*J. Chem. Phys.* **37,** 2323 (1962)) is tested by comparison with measurements of the viscosity of different colloidal systems as a function of temperature or concentration. The theory predicts that an order-disorder transition from a random array of monomers to a segmented one-dimensional helical rod will occur as the temperature is reduced to the one-dimensional freezing point or the concentration increased to the critical micelle concentration. Under these conditions an enormous increase in the solution viscosity is predicted to occur.

Semiquantitative agreement is obtained between theory and experiment for a variety of associative colloids. Fully quantitative agreement cannot be obtained because the solutions become birefringent upon aggregation of the monomers due to the large rod lengths which are obtained. Although the ordering of the rods into a birefringent liquid crystal more closely resembles the statistical mechanical theory which neglects rotation of the rods, there is unfortunately no adequate theory of the viscosity of such solutions and the Simha-Kuhn theory which we have used can only be approximate under these conditions.

Paramagnetic Resonance Spectra of Eu^{++} in CdSe and CdTe, R. S. Title, *The Physical Review* **133,** A198-A202 (January 6, 1964).

The paramagnetic resonance spectra of Eu^{++} in the semiconducting compounds CdSe and CdTe have been measured at 77°K. The results obtained are compared with those obtained by Dorain for Eu^{++} in CdS and with results for Eu^{++} in other crystals. The parameters describing the spectrum are found to be much less sensitive to changes in covalent bonding than are the parameters describing the behavior of the $3d^5$ configuration of Mn^{++} in these compounds. The variations in the parameters for Eu^{++} from compound to compound are compared with existing theories for these variations.

Paramagnetic Resonance Spectra of the $3d^5$ Configuration of Chromium in ZnSe and ZnTe, R. S. Title, *The Physical Review* **133,** A1613-A1616 (March 16, 1964).

Paramagnetic resonance measurements have been made for the $3d^5$ configuration of Cr^+ in ZnSe and ZnTe. The g factor, the cubic crystalline field parameter *a*, the hyperfine interaction with Cr^{53}, $A(Cr^{53})$ and the hyperfine interaction A_{Zn} with Zn^{67} nuclei occupying any of the twelve equivalent cation sites nearest the chromium have been determined. These resonance parameters are compared with those previously measured for Cr^+ in cubic ZnS and CdTe and the variations from crystal to crystal are found to be consistent with changes in the covalency of the bonds and with lattice distortions caused by incorporating Cr^+ substitutionally for the much smaller divalent zinc. The hyperfine interaction with Zn^{67} (or Cd^{111} and Cd^{113}) at second neighbor sites is, unlike the interaction of the isoelectronic Mn^{++} with these sites, found to vary from crystal to crystal in a manner consistent with changes in the covalent bonding.

Photoetching of Thin Lead Films with Nitromethane, L. H. Kaplan, *Journal of Physical Chemistry* **68,** 94-100 (January, 1964).

Thin evaporated lead films have been photoetched with gaseous nitromethane activated by ultraviolet radiation. The rate of etching (of the order of 10 Å/min) varies inversely with the volume of the system, is proportional to the square root of the radiation intensity, and is proportional to the partial pressure of nitromethane and then saturates at a limiting pressure. The presence of nitrogen in the system strongly retards the etching reaction. The rate of reaction has been calculated as a function of the radiation wave length by use of a set of transmission filters. For lead, the wave length band of 2680 ± 50 Å gives the largest positive contribution to the rate, while a band at 2530 ± 50 Å inhibits the reaction by about 370% of the observed rate.

Potential Energy Surface for H_3, R. N. Porter* and M. Karplus, *The Journal of Chemical Physics* **40,** 1105-1115 (February, 1964).

An analytic semiempirical expression is developed for the ground-state potential-energy surface of the H_3 system. Use is made of the valence-bond formulation with the inclusion of overlap and three-center terms. The diatomic Coulomb and exchange integrals are estimated from accurate values for the H_2 molecule by a modified London-Eyring-Sato procedure, while the three-center intergrals are approximated by simple formulas. A linear, symmetric saddle-point configuration of minimum energy is found that has properties in approximate agreement, though not identical, with other estimates from theory and experimental rate data. The details of the surface are presented in terms of contour maps for a variety of distances and angles. Because of the inclusion of overlap and three-center terms, a more realistic energy is expected for the nonlinear configurations than could be obtained from previous potential energy formulas. The utility of the present method for dynamical studies of reaction cross sections is indicated.

* Present address: Department of Chemistry, University of Arkansas, Fayetteville, Ark.

A Program System for the Automatic Issue and Revision of Illustrated Parts Catalogs, W. H. Maurer and M. L. Reynolds, *IEEE Transactions on Industrial Electronics and Control Instrumentation* **IECI-11,** No. 1, 71-78 (February, 1964).

The illustrated parts catalog issue-revision system is a group of computer (IBM 7090) programs that can be used to generate a new parts catalog or revise an old one. The basic functions of the system are to process all input data, to merge input data with a history tape of the previous-level catalog in case of a revision, and to paginate the catalog.

Quadrupole Coupling Constant, eqQ/h, of Fe^{3+} in Several Rare-Earth Iron Garnets, W. J. Nicholson and Gerald Burns, *The Physical Review* **133,** A1568-A1570 (March 16, 1964).

Using the Mössbauer effect, values of eqQ/h of Fe^{3+} have been obtained at each of two sites in several rare-earth iron garnets. The measured values of eqQ/h were compared

with values obtained using a point-charge lattice sum calculation. For the octahedral (a) site there was a reasonable agreement between the measured and calculated values of eqQ/h indicating that an ionic model is reasonably valid. However, the measured values of eqQ/h at tetrahedral (d) sites were larger than those estimated. This difference is attributed to a small amount of covalent bonding which is also evident in the values of the (d) site internal field and isomer shift.

Reduction of Turn-On and Turn-Off Time of Transistors by Differentiated Feedback, B. A. Szabo, *Solid State Design* **5,** No. 3, 11 (March, 1964).

The switching performance of a transistor can be described and analyzed by the stored-charge method, the basic equation being derived from the charge and discharge of three capacitances during the transient period. A steady-state collector current can flow only in the collector circuit if the following conditions are fulfilled: (1) the emitter transmission capacitance is completely charged up; (2) the collector transition capacitance is completely charged up; (3) the emitter diffusion capacitance responsible for the emitter current flow is charged; and (4) the minority carrier losses due to recombination are counterbalanced by an equal amount of carriers furnished to the base.

Relativistic Correction for Analytic Hartree-Fock Wave Functions, H. Hartmann* and E. Clementi, *The Physical Review* **133,** A1295-A1299 (March 2, 1964).

The relativistic energy associated with the closed-shell ground states of the atoms of the first three rows of the periodic table is computed by perturbation methods for recently obtained Hartree-Fock functions. The computations are extended to the isoelectronic series of the 2, 4, 10, 12, and 18 electron atoms with closed-shell configurations. The analysis of the data obtained reveals that, (1) different Hartree-Fock functions for a given atom give about the same realistic energy provided the number of basis functions are about the same, (2) the contribution to the relativistic energy from electrons of a given subshell is approximately a constant, independent of the number of electrons in the outer shells, (3) the empirical estimate of the relativistic energy agrees with our theoretical computation within a few percent except for low Z where the disagreement is only slightly larger.

* Present address: New York University, University Heights, New York 53, New York.

Reliable Decisions from Unreliable Measurement, Frank R. Van Wagner, *Proceedings of 7th Annual ASQC Conference,* San Bernardino Section (January 25, 1964).

The development and production of modern electronic gear and mechanisms frequently require many high precision measurements to determine if engineering requirements are being met. It is often the case that existing measurement techniques are not sufficiently precise to allow reasonable confidence in accept-reject decisions based on those measurements.

This paper develops a technique of improving the effective precision of a measurement method through a strategy of repeated measurements and artificial decision limits. One, thereby, has an alternative to developing a better measurement method, if indeed such a development is even a possible achievement.

The criteria for measurement reliability are the risks of making wrong decisions. The Quality Engineer can determine the magnitude of these risks if he ignores the measurement reliability problem by using one of the graphs in the paper. Other graphs are included to make application of the technique practical in nearly any situation involving two-sided tolerance limits.

Satellite Communications Relay System Using a Retrodirective Space Antenna, E. L. Gruenberg and C. M. Johnson, *IEEE Transactions on Antennas and Propagation* **AP-12,** No. 2, 215-223 (March, 1964).

A system has been developed for relaying messages via a satellite between earth points. In this system, messages transmitted to a satellite modulate a retrodirective antenna. Earth stations receive messages by irradiating the satellite antenna. Methods of modulating the retrodirective array are discussed with emphasis on methods to facilitate communications among several ground stations. There are advantages in spectrum usage and sharing with surface facilities. System design parameters are presented. Minimal power is required in the satellite as compared to the active communications satellites. Extremely high reliability is inherent in the design of the satellite electronic system, which can be made entirely from solid-state components.

Several Classes of Codes Generated from Orthogonal Functions, P. Hsieh and M. Y. Hsiao, *IEEE Transactions on Information Theory* **IT-10,** No. 1, 88-91 (January, 1964).

A method of designing codes from orthogonal functions utilizing the existing knowledge of discrete error-correcting binary codes is given. The method consists in constructing the transformation matrix, α_{ij}, that performs the linear transformation by taking the finite set of orthogonal functions into the set of continuous code words. Several classes of code words are found whose transformation matrices α_{ij} use symbols 0, -1, and 1, and each row of which contains equal number of nonzero elements. They are better than the randomly found existing codes in the sense that with the same number of orthogonal functions and distance criterion, more code words can be obtained.

A Simple Basis Set for Molecular Wave Functions Containing First and Second Row Atoms, Enrico Clementi, *Journal of Chemical Physics* **40,** 1944-1945 (April, 1964).

The Self-Consistent Field functions for the ground state of the first and second row atoms (from He to Ar) are computed with a basis set in which two Slater type orbitals (STO's) are chosen for each atomic orbital. The reported STO's have carefully optimized orbital exponents. The total energy is not far from the accurate Hartree-Fock energy given by Clementi, Roothaan, and Yoshimine for the first row atoms and unpublished data for the second row atoms. The obtained basis sets have sufficient flexibility to be a most useful starting set for molecular computations, as noted by Richardson. With the addition of 3*d* and 4*f* functions, the reported atomic basis sets provide a molecular basis set which will duplicate quantitatively most of the chemical information derivable by the more extended basis

set needed to obtain accurate Hartree-Fock molecular functions.

Simplified Approach to the Ground-State Energy of an Imperfect Bose Gas. II. Charged Bose Gas at High Density, E. H. Lieb and A. Y. Sakakura, *The Physical Review* **133,** A899-A906 (February 17, 1964).

Foldy, and later Girardeau, calculated the ground-state energy of a charged Bose gas at high density. We rederive the common first term obtained by these authors by using a nonperturbation method developed previously. Our aims are: (i) to establish the validity of this common result, which has not been proved; (ii) to establish the validity and usefulness of our nonperturbation method. We also show that our method will give the correct functional dependence of the ground-state energy on the density at low density, although the exact coefficient must await a numerical computation.

Size Effect of Nuclear Spin Relaxation Time in Superconducting Aluminum, Yoshika Masuda* and A. G. Redfield, *The Physical Review* **133,** A944-A947 (February 17, 1964).

Particles of aluminum having diameters less than 2000 Å were produced by evaporation in an argon atmosphere. The nuclear spin relaxation time was measured for three such samples in the normal and superconducting states between 0.36 and 1.3°K, for applied fields up to 400 G. In the normal state, and near T_c, the relaxation time is nearly the same as for bulk aluminum. Well below T_c the zero-field relaxation time is shorter than that of bulk aluminum, being less than one-fifth the bulk value at 0.4°K for two of the samples studied. At low temperatures there is also a field dependence which is characteristic of the superconducting state; T_1 increases with increasing field. At all fields, and low temperatures, the slope of a plot of $\ln T_1$ versus T_c/T indicates a gap considerably smaller than the bulk value, but the limited temperature range covered makes such conclusions dubious.

* Present address: Physics Department, Kobe University, Mikage, Kobe, Japan.

Small-Signal Amplification in GaAs Lasers, J. W. Crowe and R. M. Craig, Jr., *Applied Physics Letters* **4,** 57-58 (February, 1964).

Very large amplification factors have been obtained from GaAs laser diodes that have antireflecting end coatings and are driven with injection currents many times their nominal uncoated laser threshold. Measured values of gain as a function of current for a 10-to-1 range of light input levels are shown. For very small input signals from a GaAs oscillator diode, the gain reaches values greater than 1000.

Solid State Switching Technology—Present and Future, R. A. Henle, *Solid State Design* **5,** No. 2, 32 (February, 1964).

In the past nine years, transistors have achieved a virtually complete replacement of vacuum tubes in computer systems. With the exception of CRT's for displays, vacuum tubes are seldom utilized in machines of recent design. The characteristics of the transistor which have enabled it to achieve this take-over within this short span are: improved reliability, decreased size and power consumption, improved performance, and low cost.

Solid Transport Rate in the Vapor-Solvent Growth System ZnS:I,† F. Jona and G. Mandel, *The Journal of Physics and Chemistry of Solids* **25,** 187-190 (February, 1964).

Measurements of the rate of solid transport have been carried out in the system ZnS:I with two different sealed-tube geometries. The cubic ZnS crystals obtained are comparable in size and quality to those grown from HCl. With increasing pressure, the transport mechanism is at first diffusion—then convection controlled. In the range of diffusive flow, the pertinent theory for multireaction multicomponent systems is in satisfactory agreement with the experimental data.

† Sponsored in part by the Air Force Office of Scientific Research of the Office of Aerospace Research under Contract AF (49638)-1201.

The Solubilities and Distribution Coefficients of Zn in GaAs and GaP,† L. L. Chang, and G. L. Pearson,* *The Journal of Physics and Chemistry of Solids* **25,** 23-30 (January, 1964).

The solubilities of zinc in gallium arsenide and gallium phosphide have been measured at temperatures between 700°C and 1100°C from constant vapor source diffusion experiments using radioactive Zn^{65}. The solubilities of neutral impurities in these semiconductors can be calculated from the ionization equilibrium of impurities in the solids. By treating Zn-GaAs and Zn-GaP as binary alloys, assuming ideal liquidus solutions and considering the transfer of neutral species, the solubilities and distribution coefficients have been calculated as a function of temperature up to the melting point of the semiconductors. A sharp increase of the distribution coefficient is predicted for these systems at temperatures approaching the melting point. The intrinsic carrier concentration of GaAs and GaP at the melting point has been found to be higher than that extrapolated from the low temperature value. The relation between solid solubility and zinc vapor pressure at a fixed temperature has been investigated. Theoretical calculations give results in good agreement with the experimental data in the dilute range of zinc.

† Work performed at Stanford University.
* Stanford Electronics Laboratory, Stanford University.

A Solvable Case of the Travelling Salesman Problem, P. C. Gilmore and R. E. Gomory, *Proceedings of the National Academy of Sciences* **51,** 178-181 (February, 1964).

A solution to a special case of the travelling salesman problem and the related bottleneck travelling salesman problem is announced.

Some Recent Developments in the Design of Fluid Switching Devices and Circuits, A. E. Mitchell, H. R. Müller and R. H. W. Zingg, *Fluid Power International Conference,* 1-10 (1964).

This paper describes some of the recent developments in the design of fluid logical devices, which do not use moving

mechanical parts. They use only fluid mechanical effects to cause the switching of the streams. These developments include the design of pulsed devices. Two techniques are discussed which allow these fluid circuits to be reproduced in light-sensitive materials directly from master drawings. In miniaturized circuits the effect of manufacturing imperfections becomes important. The results of an investigation of some nonrectangular cross sections are given.

Some Results on the Stability of Nonlinear Networks Containing Negative Resistances,† Robert K. Brayton and Jürgen K. Moser,* *IEEE Transactions on Circuit Theory* **CT-11,** 165-167 (March, 1964).

This paper presents a summary of a larger paper on nonlinear networks. Several examples are given to illustrate its application.

† The results reported in this paper were obtained in the course of research jointly sponsored by the Air Force Office of Scientific Research [Contract AF 49(638)-1139] and IBM.

* Courant Institute of Mathematical Sciences, New York University.

Spherical Retrodirective Array, Elisabeth M. Rutz-Philipp, *IEEE Transactions on Antennas and Propagation* **AP-12,** No. 2, 187-194 (March, 1964).

This paper derives the characteristics of a spherically-shaped retrodirective space array. The array can receive an incoming signal over 4 pi steradians, amplify, frequency translate, and modulate this signal, and then return it in the direction of the incident wave. The directivity of the array for every angle of incidence corresponds to the area illuminated by the incoming wave. In the array the retrodirective characteristic is obtained by a phase inversion technique that is realized in tunnel-diode image frequency converters.

A circular cross section of the spherically-shaped retrodirective array is analyzed. The analysis is extended to the spherically-shaped array. It is shown that the effective aperture of a spherical array is smaller than the illuminated area. This reduction occurs because of a tapered amplitude distribution and a symmetrical phase error proportional to the frequency difference between incident wave and reradiated wave at the image frequency.

The output spectrum of the converters in the array contains not only the image frequency signal but additional frequency components as well. Because of the phase characteristics of the spectral components, only the image frequency signal when reradiated by the array elements will add coherently in direction of the incident wave. The reradiation of the other frequency components is not collimated.

Spiral Structure and Moments in Gd-Dy Alloys, R. M. Bozorth and J. C. Suits, *Journal of Applied Physics* **35,** No. 3 (Part 2), 1039-1040 (March, 1964).

Magnetic moment and electrical resistivity measurements of the Curie (T_C) and Neel (T_N) points of Gd-Dy alloys show that the region of spiral structure between T_C and T_N narrows as Gd is added to Dy and disappears at about 50 at. % Gd. Apparently no spiral structure exists in Gd or Gd-rich alloys. The magnetic moments of Dy-rich alloys show the saturation expected when the magnetization is confined to the hexagonal plane ($Jg\pi/4$), but the moments gradually approach the theoretical Jg as the Gd content increases toward 100%. The spin disorder resistivities are not linear in $(g - 1)^2 J(J + 1)$; this suggests a variation in the electronic structure of these alloys.

Spontaneous and Stimulated Infra-Red Emission from Indium Phosphide Arsenide Diodes, F. B. Alexander, V. R. Bird, D. R. Carpenter, G. W. Manley, P. S. McDermott, J. R. Peloke, H. F. Quinn, R. J. Riley and L. R. Yetter, *Applied Physics Letters* **4,** No. 1, 13-15 (January 1, 1964).

Stimulated light emission from diodes fabricated from quasi-binary III-V compound semiconductors has been reported by Holonyak for compositions in the system Ga(P_xAs_{1-x}) and, more recently, by Melngailis for two compositions in the system (In_xGa_{1-x})As. In this Letter, we report the observation of spontaneous emission from diodes fabricated from In($P_{0.18}As_{0.82}$) and both spontaneous and stimulated emission from diodes fabricated from In($P_{0.49}As_{0.51}$). Sufficient evidence of the complete miscibility of the In(P_xAs_{1-x}) system has been afforded by Folberth and by Koster and Ulrich. Compositions have been obtained from measured crystallographic lattice parameters.

Spontaneous and Stimulated Recombination in Semiconductors, G. Lasher and F. Stern, *The Physical Review* **133,** A553-A563 (January 20, 1964).

Spectral line shapes of the radiation produced by band-to-band recombination of excess carriers in semiconductors are calculated under the assumption that the momentum matrix element is the same for all initial and final states, i.e., that there is no momentum selection rule. The peak of the stimulated radiation falls at a lower photon energy than does the peak of the spontaneous radiation, except when $T = 0°K$. Some numerical results are given for simple parabolic bands, specifically for the case of electron injection into p-type GaAs, and are used to deduce the temperature dependence of the forward current which is necessary to maintain a fixed gain in the active region of a diode. The result is closely related to the temperature dependence of the threshold current in an injection laser, and gives reasonable agreement with experiment. The effect of a conduction band tail is briefly considered.

Study of Gallium Arsenide Surfaces, M. H. Pilkuhn, *The Journal of Physics and Chemistry of Solids* **25,** 141-146 (January, 1964).

Ac and dc field effect experiments have been performed on etched n and p-type GaAs samples. On (111) surfaces of n-type GaAs, quasi-equilibrium measurements are possible at very low frequencies, and a surface conductance minimum can be observed. From this the existence of acceptor levels, to a large extent bulk states, can be concluded. From optical measurements three levels (1.09, 0.88, 0.73 eV) can be deduced at room temperature. A second quasi-equilibrium situation with much larger relative conductance changes exists at high frequencies (around 8 kc/sec) where the surface appears to be n-type. The slow bulk trapping has been investigated more directly with dc measurements, and results concerning trapping times and temperature dependences are presented. On p-type samples with (110) surfaces, evidence for slow surface states, which are ambient-dependent, similar to those of Ge surfaces, has been found.

Surface-Limited Vapor Solvent Growth of Crystals, Gerald Mandel, *Journal of Chemical Physics* **40,** No. 3, 683-690 (February, 1964).

A general analysis is presented of surface reaction limitations in a vapor solvent system. A previous treatment of a multicomponent multireaction vapor diffusion limited system is extended to include finite supersaturations in the neighborhoods of the growing deposit and the etching source. The appropriate natural definitions of supersaturations are found to be in agreement with the usual conventions of irreversible thermodynamics.

A more detailed connection between the supersaturations above a growing crystal and the growth rate of the crystal is developed by means of an extension of the crystal growth theory of Burton, Cabrera, and Frank to apply to a multiple species multireaction vapor solvent system. It is found, at least in the limit of low supersaturations, that the flux of any particular species to the surface may be treated in terms of the formalism developed by Burton, Cabrera, and Frank for a monatomic crystal-monatomic vapor system, except that some of the parameters which characterize the process, e.g., diffusion length on the surface, lifetime on the surface, etc., have more phenomenological character. Relationships between the fluxes of different species are developed in the same manner as in the previously treated vapor diffusion limited system.

Quantitative calculation of the important parameters is apparently impossible in our present state of knowledge of surface processes. Qualitatively, we expect surface diffusion effects to be far more important than in simple crystal-vapor systems. Other effects, however, are also expected to be important in vapor solvent systems, e.g., "kink-reaction" limitations, impurity effects, etc. Disentanglement of these several processes is an unsolved problem and it is concluded that detailed quantitative understanding of surface-limited crystal growth in a vapor solvent system is presently out of reach.

A Synopsis of Magnetic Memories, Hsu Chang, *Proceedings of the INTERMAG Conference,* 5-2-1 to 5-2-4 (April, 1964).

Magnetic memories abound in shapes and in materials. The present paper considers the major physical phenomena underlying the operations of the magnetic elements, the circuitry and the transmission line array. Our purpose is to formulate a few ground rules for memory design and to determine the ultimate limitations. Some future improvements are also indicated.

A Technique for Computer Detection and Correction of Spelling Errors, F. Damerau, *Communications of the ACM* **7,** 171-176 (March, 1964).

The method described assumes that a word which cannot be found in a dictionary has at most one error, which might be a wrong, missing or extra letter or a single transposition. The unidentified input word is compared to the dictionary again, testing each time to see if the words match—assuming one of these errors occurred. During a test run on garbled text, correct identifications were made for over 95 percent of these error types.

Temperature Dependence of the Critical Fields of Thin Superconducting Films, A. M. Toxen, *Review of Modern Physics* **36,** No. 1 (Part 1), 308-312 (January, 1964).

Using a simple strong-field, nonlocal theoretical model, calculations have been carried out for the temperature dependence of the critical fields of superconducting films. Comparison of the theoretical results to measurements of the temperature variation of critical field of pure indium and indium-tin alloy films yields fairly good agreement when the Pippard kernel is used in the calculation. However, small but consistant discrepancies are noted. Preliminary calculations with the BCS kernel, carried out in the thin and impure limits, indicate that the discrepancies previously noted can be partially (or perhaps completely) resolved by the use of the BCS kernel in the theoretical calculation.

Temperature Variation Effects on Dimensional Accuracy in the Machining of Aluminum, D. Weisman, *Tool and Manufacturing Engineer* **52,** 91-96 (February, 1964).

This paper is an investigation of temperature variation effects on dimensional accuracy in the machining of aluminum. It examines the thermal expansion differences between aluminum and steel and discusses the techniques of controlling the aluminum work-steel gage dimensional difference. Tolerance ranges are presented for appraisal of the dimensional error with reference to $\pm 0.000050''$, $\pm 0.0001''$, and $\pm$ $0.00025''$. This investigation is significant for manufacturing capability in the manufacture of precision components.

Theory of Electrical Resistivity of Ferromagnetic Metals, S. H. Liu, *Journal of Applied Physics* **35,** No. 3 (Part 2), 1087-1088 (March, 1964).

This paper gives a brief account of a new calculation of the electrical resistivity of ferromagnetic metals on the *s-d* or *s-f* exchange model. It points out that the conventional treatment of the problem taking the *s-d* interaction as a small perturbation to a system of free electrons and ferromagnetically coupled spins is basically inconsistent with the indirect exchange theory. The consistent formulation of the problem is then given with the help of the Kubo method of electrical conductivity. The correlation functions involved in the Kubo formula are evaluated by the equation of motion method for many body problems. The hierarchy of equations of motion is terminated at a finite order by the decoupling approximation. The resulting equations are solved and the solutions are used to calculate the conductivity. A new result that comes out of this theory is that the low-temperature electrical resistivity is proportional to the density of spin waves and has a $T^{3/2}$ dependence on the temperature T. This result is in quantitative agreement with the experimental findings of Kondorsky et al.

Thin-Film Circuit Technology, Part I, A. E. Lessor, L. I. Maissel and R. E. Thun, *IEEE Spectrum* **1,** No. 4, 72 (April, 1964).

Miniaturization requirements have brought about the integral fabrication of many components. The thin-film approach permits the integration of numerous precision circuit

elements and their interconnections. Part I of this three-part series deals mainly with the two deposition techniques of cathode sputtering and vacuum evaporation, and with their use in the fabrication of film resistors, capacitors, and R-C networks. Subsequent articles will discuss thin-film transistors and cryogenic thin films.

Thin-Film Circuit Technology, Part II, H. L. Caswell, *IEEE Spectrum* **1,** No. 5, 84 (May, 1964).

Thin-film techniques have contributed significantly to an improved understanding of superconductivity. Cryogenic thin films are particularly suitable for use in switching and storage devices in computer memories.

Transient Charge Transfer in Gaseous Rubidium-Benzene Collisions, Richard G. Brewer, *The Journal of Chemical Physics* **40,** 1077-1081 (February, 1964).

The interaction that arises during gas-phase rubidium-atom-benzene-molecule collisions has been investigated through Rb^{87} hyperfine frequency measurements which utilize optical double resonance. An unusually large hyperfine-splitting shift of −137000 cps/cm Hg of benzene vapor is observed. In contrast to previous studies with other buffer gases, the shift is too large to be explained by a mechanism involving either Pauli exclusion or van der Waals forces. When the shift is interpreted in terms of an adiabatic collision model following the theory of Foley for the pressure broadening of spectral lines, it is seen that the unpaired-electron density at the Rb nucleus is reduced about 8% during an average collision. This behavior is attributed to a partial and transient electron transfer to the benzene ring. A comparison with ESR studies of liquid media where the alkali valence electron resides dominantly on the aromatic ring illustrates the importance of the solvent in facilitating electron transfer.

Transit Time in High-Speed Switching Transistors, K. G. Ashar, *Solid State Design* **5,** No. 2, 24 (February, 1964).

The meaning measurement and application of transit time are discussed in this paper. The relative merits of this quantity as compared to more common parameters in high-system switching devices are pointed out. Uses of the transit time in studying high level injection effects and circuit transient evaluations are indicated.

Transmission of Isotropic Radiation Across an Interface Between Two Dielectrics,† Frank Stern, *Applied Optics* **3,** 111-113 (January, 1964).

Expressions for the transmissivity of an interface between two dielectrics, averaged over all directions of incidence and over all polarization directions, are given, and the results are tabulated and graphed. When the radiation is incident from the medium with lower index of refraction, the average transmissivity $T_{av}(n)$ differs from the transmissivity at normal incidence by less than 6% for values of the ratio of the indices of refraction n between 1 and 8. The average transmissivity when the light is incident from the high-index side of the interface is smaller than $T_{av}(n)$ by a factor n^{-2}. The connection of the results with the blackbody flux in a dielectric is noted. The results are used to estimate the energy density in a dielectric when isotropic radiation is generated internally.

† Work performed at U. S. Naval Ordnance Laboratory, White Oak, Silver Spring, Maryland.

Transverse Ferroacoustic Resonance, B. Lüthi and F. Oertle, *Physics of Condensed Matter* **2,** No. 2, 99-116 (January 24, 1964).

Experimental results on the transverse ferroacoustic resonance in yttrium iron garnet and in gallium substituted yttrium iron garnets are reported. A detailed comparison with theory is made. The occurrence of the resonance for different geometries is discussed and the magnitude of the resonance magnetic field is quantitatively understood. In a similar way as in ferromagnetic resonance, one can deduce the anisotropy constant from the change of the resonance field with temperature. From the line shape of the resonance, only in a few cases are we able so far to get a relaxation time out of it, mostly because of disturbing line broadening effects.

TRL Circuit Design Implemented by Computer, C. L. Hegedus, *Electronic Design* **12,** No. 6, 40-46 (March 16, 1964).

The mathematical discussion of the loop equations for a two-stage TRL switching block provides an excellent tool to design reliable circuits which also fulfill the criteria for fast switching, as well as the most economical combinations of the number of input and output stages.

The three equations used describe the mathematical relation between the coupling and biasing resistors R_1 and R_2, respectively, when the operating collector current is selected to attain the best current amplification factor. Utilizing this principle, the collector voltage can be minimized to speed up the turn-on and turn-off transition while the known magnitude of the off-bias voltage across the base-emitter junction can be kept low to minimize turn-on delay coupled with the suitable magnitude of the pull-off base current which has a dominant influence on the turn-off delay.

The calculations to obtain all values of voltages and currents as well as the resistors can be carried out for random numbers of inputs and outputs.

Ultrasonic Traveling-Wave Parametric Amplification in MgO, N. S. Shiren, *Applied Physics Letters* **4,** 82-85 (February 15, 1964).

Utilizing the nonlinear acoustic interaction in MgO and the associated techniques previously reported, we have produced parametric amplification of pulsed 8.5-Gc/sec ultrasonic waves. The frequency of the acoustic pump wave was 16.45 Gc/sec. The pump and signal (and, therefore also idler) waves were longitudinally polarized and propagated on the ⟨100⟩ crystal axis. The maximum acoustic power gain observed was 3.5 dB over a 2-cm propagation path.

Universality of Tag Systems With P = 2, J. Cocke and M. Minsky,* *Journal of the Association for Computing Machinery* **11,** No. 1, 15-20 (January, 1964).

By a simple direct construction it is shown that computations done by Turing machines can be duplicated by a very simple symbol manipulation process. The process is de-

scribed by a simple form of Post canonical system with some very strong restrictions.

This system is *monogenic:* each formula (string of symbols) of the system can be affected by one and only one production (rule of inference) to yield a unique result. Accordingly, if we begin with a single axiom (initial string) the system generates a simply ordered sequence of formulas, and this operation of a monogenic system brings to mind the idea of a machine.

The Post canonical system is further restricted to the "Tag" variety. Tag systems are equivalent to Turing machines. The previous proof is very complicated and uses lemmas concerned with a variety of two-tape nonwriting Turing machines. The proof here avoids these otherwise interesting machines and strengthens the main result; obtaining the theorem with a best possible *deletion number* $P = 2$.

These systems seem to be of value in establishing unsolvability of combinatorial problems.

* Massachusetts Institute of Technology, Computation Center and Department of Electrical Engineering.

Letters to the Editor

Bindungsscherung in elastisch verformtem Germanium (Bondbending in strained germanium), A. Segmüller, *Helvetica Physica Acta* **36,** No. 5, 486 (August 15, 1963).

Harmonic Generation in Injection Lasers, A. W. Smith, M. I. Nathan, J. A. Armstrong, A. E. Michel and K. Weiser, *Journal of Applied Physics* **35,** No. 3 (Part 1), 733-734 (March, 1964).

InP Laser Characteristics, K. Weiser, R. S. Levitt, M. I. Nathan, G. Burns and J. Woodall, *Transactions of the Metallurgical Society of AIME* **230,** 271 (1964).

Magnetism, (Report on 9th Annual Conference on Magnetism and Magnetic Materials), S. H. Charap and R. F. Elfant, *Science* **143,** 604-611 (February 7, 1964).

Messung der optischen Konstanten des Gadoliniums im Ultrahochvakuum (Measuring the optical constants of gadolinium in ultra-high vacuum), C. Schüler and W. E. Müller, *Helvetica Physica Acta* **36,** No. 5, 487 (August 15, 1963).

Optical Harmonic Generation in Two Ferroelectric Crystals, A. W. Smith, *Applied Optics* **3,** 147-150 (1964).

Synthesis of Active RC One-Ports Using Generalized Impedance Converters,† S. K. Mitra* and N. M. Herbst, *IEEE Transactions on Circuit Theory* **CT-10,** 532 (December, 1963).

† This research was done at Cornell University and was supported by the Air Force Avionics Laboratory, Air Force Systems Command, U. S. Air Force.
* Cornell University, Ithaca, New York.

Temperature Dependence of Spin Wave Energies, S. H. Charap, *Bulletin of the American Physical Society* **119,** No. 1, 112 (1964).